

Non-linear World – switching from linear to non-linear modelling

Alpine snow cover – “Water Tower” for Humanity

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The main aim of the presented research is two-folded:

- I. to provide a new and much needed methodology to improve spatial and temporal snow cover estimations in the complex alpine-forested regions,
- II. to provide a comprehensive comparison between linear and non-linear models set in the Artificial Neural Networks (ANNs) framework to estimate Landsat Fractional Snow Cover (Landsat-FSC) in complex alpine-forested environments.

The ANN Landsat-FSC was delivered through data fusion between IKONOS ground-based binary classification snow/non-snow (1 m spatial resolution) and Landsat multispectral images (30 m spatial resolution).

IKONOS binary snow/no-snow classification



ANN non-linear and linear models for snow cover

Error evaluation

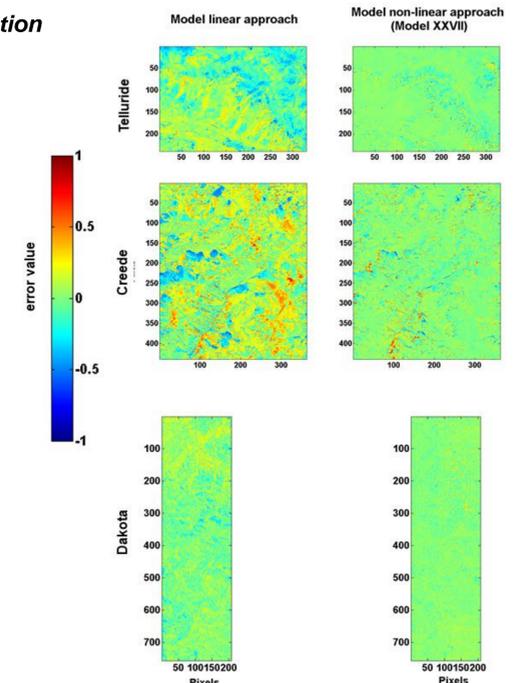


Figure 5. ANN Landsat-FSC estimation based on linear and non-linear models

Both ANN Landsat-FSC models, ANN Landsat-FSC_{non-linear} and ANN Landsat-FSC_{linear}, used the same ANN architecture and the same input data (15 data inputs) to simulate Landsat FSC. The only difference between both models are activation functions.

In ANN LandsatFSC_{linear} model – a linear activation function was used during the training process.

ANN LandsatFSC_{linear} model indicates significantly lower performance when compared to ANN LandsatFSC_{non-linear} model.

Research area

Datasets	IKONOS	Landsat TM/ETM+
Fresh snow cover	Telluride, CO 2008-10-12	'snow' 2008-10-12
Full snow cover	Creede, CO 2000-12-18	'vegetation' 2007-09-08
'Old' snow cover	Black Hills, SD 2003-02-25	2000-12-18
		2002-08-26
		2002-09-03

ANN Landsat-FSC training is based on combined image datasets from Creede, CO, Telluride, CO, and Black Hills, SD. 98 000 points (pixels) were used in the training process.

ANN Landsat-FSC validation is performed on individual images:
- Telluride, CO, San Juan Mountains, 79 000 points;
- Creede, CO, San Juan Mountains, 159 000 points;
- Black Hills, SD, 149 000 points.

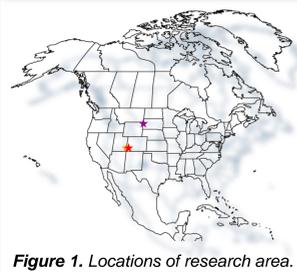


Figure 1. Locations of research area.

IKONOS panchromatic band (1 m² spatial resolution) was fused with IKONOS multispectral bands: green, red, near-infrared (4 m² spatial resolution) through wavelet transformation.

Discrimination between snow/no-snow was accomplished using Normalized Difference Vegetation Index (NDVI). NDVI threshold was determined based on spectral mixing model (Scattering by Arbitrarily Inclined Leaves Model). In this presentation NDVI threshold was set to 0.07.

30 m IKONOS Fractional Snow Cover (IkonoFSC) is established as cumulative average of snow / no-snow 1m² binary classification.

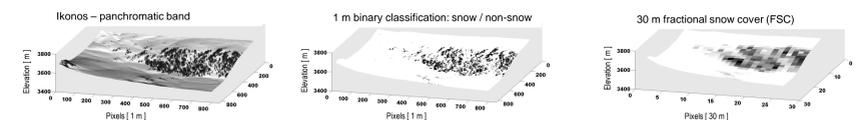


Figure 3. IkonoFSC as a ground truth for Landsat snow cover estimation during ANN fusion.

ANN Landsat & MODIS Fractional Snow Cover

Results: ANN Landsat Fractional Snow Cover

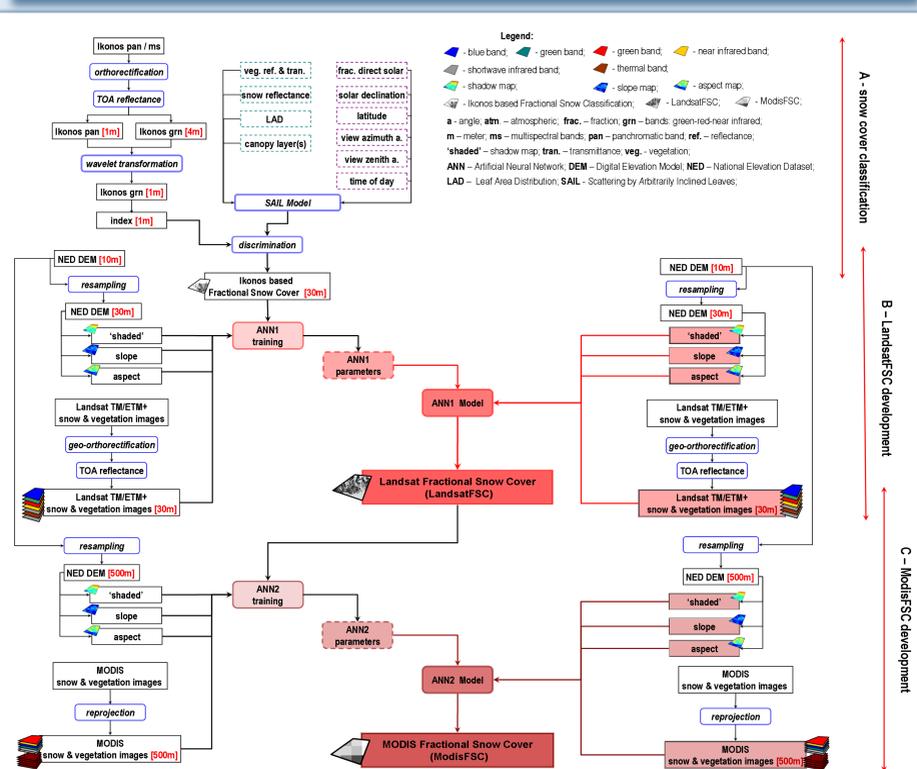


Figure 2. Information flow for ANN Landsat-FSC and Modis-FSC development.

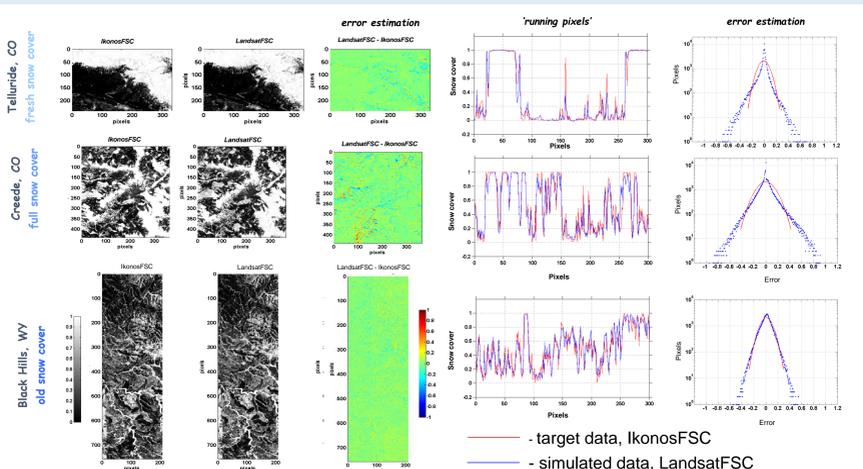


Figure 4. ANN Landsat-FSC estimations for Telluride, Creede, CO and the Black Hills of South Dakota, WY

The ANN Landsat-FSC model represents the first attempt to develop an estimator of fractional snow values from actual ground equivalent reference data and non-linear modeling

It is the first endeavor to estimate FSC values by combining terrain and reflectance data

ANN Landsat-FSC exhibits:

very low error values: **mean error ~ 0.1%**

high correlation with the ground equivalent reference: **R² ~ 0.9**

The ANN non-linear model indicates high plasticity and a high ability to adopt to complex data information found in alpine-forested environments.

The results of the research have moved us towards the conclusion that the nature of the relationships between vegetation, snow, and terrain heterogeneity in alpine-forested environments, indicate a non-linear complex behavior. **Natural environments indicate strong non-linear relations among its endmembers.**

Mountains are environmental sky-islands, and research investigating their distinct compound complexity needs 'sky-island' specific input data and methodologies

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